CLAIMS

What is claimed is:

1. An apparatus to limit power to a load, comprising:

a power source to drive the load using an input signal;

a voltage monitor coupled to the power source to detect a voltage supplied by the power source and to provide a voltage signal representative of said voltage;

a current monitor coupled to the power source to detect a current supplied by the power source and to provide a current signal representative of said current;

the control circuit to receive said voltage signal and said current signal, said control circuit to provide a value based on said voltage signal and said current signal according to one or more control parameters; and,

a signal attenuator coupled to the power source and the control circuit, the signal attenuator to limit said input signal based on said value.

2. The apparatus of claim 1 further comprising an amplifier coupled to the power source and the load.

3. The apparatus of claim 2 wherein the amplifier includes the voltage monitor and the current monitor.

4. The apparatus of claim 1 wherein the voltage signal is sampled by a first analog-to-digital converter to generate a digital voltage signal.

5. The apparatus of claim 4 wherein the current signal is sampled by a second analog-to-digital converter to generate a digital current signal.

6. The apparatus of claim 5 wherein the control circuit further comprises a multiplier to receive the digital voltage signal and the digital current signal, and to calculate an instantaneous power.

7. The apparatus of claim 1 wherein the control circuit implements a linear gain control.

8. The apparatus of claim 1 wherein the control circuit implements a nonlinear gain control.

9. The apparatus of claim 1 wherein the control circuit implements a recursive gain control.

10. The apparatus of claim 1 wherein the control circuit implements a non-recursive gain control.

11. The apparatus of claim 1 wherein the one or more control parameters comprises a power averaging time and a power threshold.

12. The apparatus of claim 11 wherein the one or more control parameters further includes an attack time and a release time.

13. The apparatus of claim 11 wherein an averaging coefficient (T_A) is calculated by the control circuit using the power averaging time according to $T_A = e^{\frac{-n}{t_a f_S}}$, where n is a filter order, t_a is the power averaging time in seconds, and f_s is a sampling frequency.

14. The apparatus of claim 12 wherein said value is a gain value, and wherein the control circuit calculates the gain value using the power threshold expressed as follows:

$$gain = \sqrt{\frac{P_T A_I A_V}{L}},$$

where L is an averaged power level, P_T is the power threshold, A_I is a corrective factor for the current signal, A_V is a corrective factor for the voltage signal and T_R is a release coefficient.

15. The apparatus of claim 14 wherein the release coefficient is calculated by the control circuit according to,

$$T_R = e^{\frac{-n}{t_R f_S}},$$

where n is a filter order, t_R is the release time, and f_s is a sampling frequency.

16. The apparatus of claim 1 wherein the one or more control parameters are selected from a library of control parameters that is accessible using a graphical user interface.

17. The apparatus of claim 16 wherein the load is a loudspeaker and the library of control parameters comprises optimized control parameters for a plurality of particular loudspeakers.

18. The apparatus of claim 17 wherein the one or more control parameters are selected by a user from the library of control parameters by selecting from a list of available loudspeakers using the graphical user interface.

19. The apparatus of claim 1 wherein the one or more control parameters are manually provided to the control circuit by a user.

20. The apparatus of claim 1 wherein said one or more control parameters comprises a thermal threshold value.

21. The apparatus of claim 20, wherein the thermal threshold value is calculated according to,

$$\frac{R_T}{R_0} = 1 + \alpha\left(T_T - T_0\right) + \beta\left(T_T - T_0\right)^2,$$

where α and β are thermal coefficients of resistance, T_0 is a resistance of said load at ambient temperature and T_T is a threshold temperature of the load.

22. The apparatus of claim 21, wherein said value is a gain value, and wherein the control circuit calculates said gain value using the thermal threshold value expressed as follows:

$$gain = \frac{R_0 A_I I}{R_T A_V I_0},$$

where A_I is a corrective factor for the current signal, A_V is a corrective factor for the voltage signal, I_0 is representative of a modeled current and I is representative of a measured current.

23. An apparatus to limit power to a load, comprising:

a power source to drive the load;

a monitor coupled to the power source to detect a power level supplied by the power source and to provide a power signal representative of said power level;

the control circuit to receive said power signal and to provide a value based on said power signal according to one or more control parameters; and,

a signal attenuator coupled to the power source and the control circuit, the signal attenuator to limit said power level based on said value.

24. The apparatus of claim 23 further comprising an amplifier coupled to the power source and the load.

25. The apparatus of claim 24 wherein the amplifier includes the monitor.

26. The apparatus of claim 23 wherein the power signal is sampled by an analog-to-digital converter to generate a digital power signal.

27. The apparatus of claim 26 wherein the control circuit further comprises a multiplier to receive the digital power signal, and to calculate an instantaneous power.

28. The apparatus of claim 23 wherein the control circuit implements a linear gain control.

29. The apparatus of claim 23 wherein the control circuit implements a nonlinear gain control.

30. The apparatus of claim 23 wherein the control circuit implements a recursive gain control.

31. The apparatus of claim 23 wherein the control circuit implements a non-recursive gain control.

32. The apparatus of claim 23 wherein the one or more control parameters includes a power averaging time and a power threshold.

33. The apparatus of claim 32 wherein the one or more control parameters further includes an attack time and a release time.

34. The apparatus of claim 32 wherein an averaging coefficient (T_A) is calculated by the control circuit using the power averaging time according to $T_A = e^{\frac{-n}{t_a f_S}}$, where n is a filter order, t_a is the power averaging time in seconds, and f_s is a sampling frequency.

35. The apparatus of claim 33 wherein said value is a gain value, and wherein the control circuit calculates the gain value using the power threshold according to,

$$gain = \sqrt{\frac{P_T A_I A_V}{L}},$$

where L is an averaged power level, P_T is the power threshold, A_I is a corrective factor for the current signal, A_V is a corrective factor for the voltage signal and T_R is a release coefficient.

36. The apparatus of claim 35 wherein the recovery coefficient is calculated by the control circuit expressed as follows:

$$T_R = e^{\frac{-n}{t_R f_S}},$$

where n is a filter order, t_R is the release time and f_s is a sampling frequency.

37. The apparatus of claim 23 wherein the one or more control parameters are selected from a library of control parameters that is accessible using a graphical user interface.

38. The apparatus of claim 37 wherein the load is a loudspeaker and the library of control parameters contains optimized control parameters for a plurality of particular loudspeakers.

39. The apparatus of claim 38 wherein the one or more control parameters are selected by a user from the library of control parameters by selecting from a list of available loudspeakers using the graphical user interface.

40. The apparatus of claim 23 wherein the one or more control parameters are manually provided to the control circuit by a user.

41. The apparatus of claim 23 wherein said one or more control parameters comprises a thermal threshold value.

42. The apparatus of claim 41, wherein the thermal threshold value is calculated according to,

$$\frac{R_T}{R_0} = 1 + \alpha(T_T - T_0) + \beta(T_T - T_0)^2,$$

where α and β are thermal coefficients of resistance, T_0 is a resistance of said load at ambient temperature and T_T is a threshold temperature of the load.

43. The apparatus of claim 42, wherein said value is a gain value, and wherein the control circuit calculates said gain value using the thermal threshold value expressed as follows:

$$gain = \frac{R_0 A_I I}{R_T A_V I_0},$$

where A_I is a corrective factor for the current signal, A_V is a corrective factor for the voltage signal, I_0 is representative of a modeled current and I is representative of a measured current.

44. A method for limiting power to a load comprising:

driving the load with an input signal;

providing a voltage signal that is representative of a voltage of the input signal;

providing a current signal that is representative of a current of the input signal;

calculating a value based on said voltage signal and said current signal according to one or more control parameters; and,

limiting the input signal based on the value.

45. The method of claim 44 further comprising amplifying the input signal before said driving the load with the input signal.

46. The method of claim 44 further comprising generating a digital voltage signal by sampling the voltage signal with a first analog-to-digital converter.

47. The method of claim 44 further comprising generating a digital current signal by sampling the current signal with a second analog-to-digital converter.

48. The method of claim 47 further comprising calculating an instantaneous power by combining the digital voltage signal and the digital current signal.

49. The method of claim 44 further comprising implementing linear gain control using a control circuit that is used for said calculating the gain value.

50. The method of claim 44 further comprising implementing nonlinear gain control using a control circuit that is used for said calculating the gain value.

51. The method of claim 44 further comprising implementing recursive gain control using a control circuit that is used for said calculating the gain value.

52. The method of claim 44 further comprising implementing non-recursive gain control using a control circuit that is used for said calculating the gain value.

53. The method of claim 44 wherein the one or more control parameters includes a power averaging time and a power threshold.

54. The method of claim 53 wherein the one or more control parameters further includes an attack time and a release time.

55. The method of claim 53 further comprising calculating an averaging coefficient (T_A) using the power averaging time according to $T_A = e^{\frac{-n}{t_a f_S}}$, where n is a filter order, t_a is the power averaging time in seconds, and f_s is a sampling frequency.

56. The method of claim 54 wherein said value is a gain value, the method further comprising calculating the gain value using the power threshold according to,

$$gain = \sqrt{\frac{P_T A_I A_V}{L}},$$

where L is an averaged power level, P_T is the power threshold, A_I is a corrective factor for the current signal, A_V is a corrective factor for the voltage signal and T_R is a release coefficient.

57. The method of claim 56 further comprising calculating the release coefficient according to,

$$T_R = e^{\frac{-n}{t_R f_S}},$$

where n is a filter order, t_R is the release time and f_s is a sampling frequency.

58. The method of claim 44 further comprising selecting the one or more control parameters from a library of control parameters that is accessible using a graphical user interface.

59. The method of claim 58 wherein the load is a loudspeaker and the library of control parameters comprises optimized control parameters for a plurality of particular loudspeakers.

60. The method of claim 59 wherein said selecting the one or more control parameters comprises selecting the one or more control parameters from the library of control parameters by selecting from a list of available loudspeakers using the graphical user interface.

61. The method of claim 44 further comprising manually selecting the one or more control parameters by a user.

62. The method of claim 44 wherein said one or more control parameters comprises a thermal threshold value.

63. The method of claim 62, further comprising calculating the thermal threshold value expressed as follows:

$$\frac{R_T}{R_0} = 1 + \alpha\left(T_T - T_0\right) + \beta\left(T_T - T_0\right)^2,$$

where α and β are thermal coefficients of resistance, T_0 is a resistance of said load at ambient temperature and T_T is a threshold temperature of the load.

64. The method of claim 63, wherein said value is a gain value, and wherein the method further comprises calculating said gain value using the thermal threshold value according to,

$$gain = \frac{R_0 A_I I}{R_T A_V I_0},$$

where A_I is a corrective factor for the current signal, A_V is a corrective factor for the voltage signal, I_0 is representative of a modeled current and I is representative of a measured current.

65. A method for limiting power to a load comprising:

driving the load with an input signal from a power source;

providing a power signal that is representative of a power level of the input signal;

calculating a value based on said power signal according to one or more control parameters; and,

limiting the input signal based on the value.

66. The method of claim 65 further comprising generating a digital power signal by sampling the power signal with a analog-to-digital converter.

67. The method of claim 65 further comprising calculating an instantaneous power based on the digital power signal.

68. The method of claim 65 wherein the one or more control parameters includes a power averaging time, a power threshold, an attack time and a release time.

69. The method of claim 68 further comprising calculating an averaging coefficient (T_A) using the power averaging time according to $T_A = e^{\frac{-n}{t_a f_S}}$, where n is a filter order, t_a is the power averaging time in seconds, and f_s is a sampling frequency.

70. The method of claim 68 wherein the value is a gain value, and the method further comprises calculating the gain value using the power threshold according to,

$$gain = \sqrt{\frac{P_T A_I A_V}{L}},$$

where L is an averaged power level, P_T is the power threshold, A_I is a corrective factor for the current signal, A_V is a corrective factor for the voltage signal and T_R is a release coefficient.

71. The method of claim 70 further comprising calculating the release coefficient according to,

$$T_R = e^{\frac{-n}{t_R f_S}},$$

where n is a filter order, t_R is the release time and f_s is a sampling frequency.

72. The method of claim 65 further comprising selecting the one or more control parameters from a library of control parameters that is accessible using a graphical user interface, and wherein said load is a loudspeaker and the library of control parameters contains optimized control parameters for a plurality of particular loudspeakers.

73. The method of claim 72 wherein said selecting the one or more control parameters comprises selecting the one or more control parameters from the library of control parameters by selecting from a list of available loudspeakers using the graphical user interface.

74. The method of claim 65 wherein said one or more control parameters comprises a thermal threshold value.

75. The method of claim 74 further comprising calculating the thermal threshold value according to,

$$\frac{R_T}{R_0} = 1 + \alpha(T_T - T_0) + \beta(T_T - T_0)^2,$$

where α and β are thermal coefficients of resistance, T_0 is a resistance of said load at ambient temperature and T_T is a threshold temperature of the load.

76. The method of claim 75, wherein said value is a gain value, and wherein the method further comprises control circuit calculates said gain value using the thermal threshold value expressed as follows:

$$gain = \frac{R_0 A_I I}{R_T A_V I_0},$$

where A_I is a corrective factor for the current signal, A_V is a corrective factor for the voltage signal, I_0 is representative of a modeled current and I is representative of a measured current.